Creating music by means of 'physical thinking': the musician oriented genesis environment

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CREATING MUSIC BY MEANS OF 'PHYSICAL THINKING': THE MUSICIAN ORIENTED GENESIS ENVIRONMENT

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ABSTRACT

Mass-interaction physical modeling scheme is often cited as the traditional physical modeling technique, but surprisingly some of the possibilities for musical creation it allows have not yet been pointed out.

GENESIS is a graphical environment based on the CORDIS-ANIMA mass-interaction paradigm and designed for musicians. It was conceived so as to help the user "think physical"; that is, to discover and experiment with new ways of creating music, which is necessary when using physical modeling.

The paper introduces version 1.5 of the GENESIS environment. Its major features and ergonomic aspects are exposed – especially model representation, low and high level modeling tools, multisensorial simulation facilities. Examples of composer's works are presented.

1. INTRODUCTION

Physical Modeling (PM) is increasingly used for musical purposes. It is generally believed to allow [1], [2], [3], [4]:

A more convincing synthesis of real instruments' sounds;

More generally, a better plausibility of synthesized sounds even with chimera models that have no real counterparts. This is musically very interesting since human hearing appreciates being able to infer a possible cause to sounds [5] ;

An easier and more natural mapping of dynamic inputs inside models, through force or position variables;

As a consequence of the above points more interesting sounds and better expressive possibilities.

However, PM is usually considered as a new approach to sound synthesis. We believe it is of a great interest as a very much more general means for computer music creation. As such, the design and use of physical models by musicians obviously needs new ways of thinking. A short but appropriate slogan would be: "think physical". A software environment dedicated to musicians should help them to accomplish this radical change in their mental approach to sounds and music. This is not an easy-to-reach goal, which explains, perhaps, the lack of such environments today.

This article introduces the musician-oriented GENESIS environment based on the mass-interaction paradigm CORDIS-ANIMA [6]. As a first step, we emphasize the interest of the mass-interaction paradigm in comparison with other PM schemes. The CORDIS-ANIMA system is then briefly described. We expose the main features and ergonomic properties of the GENESIS' "Lutherie" workbench. The choices we made to support the user's creative process are explained. As a final step, we refer to works by composers that demonstrate a "physical way of thinking" and illustrate the way PM may be a general means for creating music rather than just sound synthesis.

2. 1D MASS-INTERACTION PARADIGM

Different approaches to PM present different benefits. Among them, the mass-interaction paradigm:

Is not specifically dedicated to sound structures, but more generally to the modeling of matter. Both low frequency and high frequency objects can be combined and different musical scales of time conceptualized within the same formalism.

Allows a highly modular modeling process. A model is composed of very elementary modules. Each of these grains of matter has an easy to comprehend physical behavior.

Enables an efficient and natural mental model of algorithms, which helps in reducing the gap between reality and "virtuality". Models are more easily internalized as representations of real objects than with more mathematical or signal processing PM approaches.

These characteristics, especially the last, shows that mass-interaction paradigm is particularly interesting when the aim is to let a non-physicist musician create the entirety of his musical material, including modeling.

The GENESIS environment we present below is based on the topological CORDIS-ANIMA [6], [7] mass-interaction system. A CORDIS-ANIMA model is a network of elementary modules of two kinds: mass-like elements <MAT>, and physical relations <LIA> which connect them to each other. In addition to the traditional linear modules (such as fixed-point, inertia, stiffness, damping, etc., called respectively SOL, MAS, RES, FRO within CORDIS-ANIMA…), two – and only two – non-linear interactions [8] are defined:

First, the BUT module, which models contact through an interaction conditioned to position. When the masses interconnected are far from each other, no force is applied. When they get closer, a visco-elastic interaction appears. The BUT is used for example to model percussion.

Second, the LNL, which groups together a non linear viscosity and a non-linear elasticity. A LNL is made of two point-by-point curves that can be smoothed. The first curve defines the force to be applied according to the distance of the two connected masses. The second curve defines the force to be applied according to the relative velocities of the two masses. This non-linear interaction allows the modeling of complex non-linear interactions between objects. Among the simplest, for example, it is possible to simulate plucking interactions or bow/object interactions.

In the topological version of CORDIS-ANIMA implemented in GENESIS, the mass-like elements move and the forces are applied along a single axis. The use of such a 1D simulation space allows at the same time higher speed simulations, easier modeling and interesting sounds and models.

3. THE GENESIS' "LUTHERIE" WORKSHOP

The design of GENESIS had four main goals:

As a basic philosophy, let the user operate at an elementary level and experiment with the basic physical behavior of matter.

Introduce high level modeling tools to manage a group of modules as a whole when desired.

Provide a complete musical creation environment, that is let GENESIS be, when desired, the main and central software in the electroacoustic studio.

Help the user in changing his creative processes and in developing a 'physical thought', which we think is necessary for the optimal use of PM.

3.1. The 'Lutherie' workbench

GENESIS implements a "direct manipulation" approach to human-computer interaction [9], [10], so that users can interact as directly as possible with modules and objects during modeling.

3.1.1. Representation of the modules and objects

The graphical 2D representation we propose (figure 1) is a metaphor of an instrument-maker or "lutherie" workbench. A module's representation implies the use of shape, size, hue and intensity of color with the main following properties:

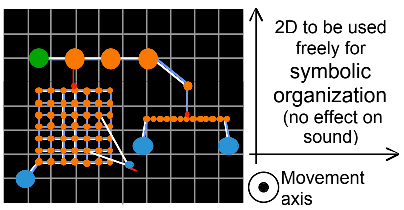


Figure 1: *The "Lutherie" workbench metaphor. The simulation axis is perpendicular to the workbench.*

Shape represents the module's category - circles for physical <MAT> modules, lines for <LIA>, squares for input-output modules.

Hue indicates the module's behavior. For example: orange for MAS, white for REF, etc.

Size represents the scale of the main parameter of the module. GENESIS defines a series of steps in size that correspond to a series of increasing "preferred values" for the parameter. The size of MAT modules is chosen according to the inertia value. LIA thickness codes the aptitude of LIA to influence MAT movements.

Color intensity is a less perceptible display attribute. It is used as a secondary indicator to indicate finer variations in the main parameter. This lets the user perceive heterogeneity among modules.

These choices optimize the information users can easily acquire by looking at the workbench. Moreover, they no doubt help models be perceived as objects, and not only as mathematical or algorithmical constructions. They enhance the modeling process and encourage a physical way of thinking.

Due to the use of the one dimensional mass interaction scheme, masses move only on the axis perpendicular to the workbench. The two axes of the workbench do not have any effect on the phenomena generated. They are left to organize freely the model, and to carry symbolic information. Usually, they allow the evocation of real objects by positioning the modules. They may also underline a behavior of a specific part of an object, symbolize time from left to right, physically express some kind of partitioning, or even allow a pictorial approach to modeling.

3.1.2. Navigation within the workbench

The "lutherie" workspace can be as large as needed – let's say 1000 m^2 for example – and each object may be composed of a large number of modules – up to 10 000 in some complex works. We gave special attention in the design to particularly efficient and easy-to use zooming and panning features.

3.2. Basic editing functionalities

Modularity is a key-word when using the mass-interaction modeling scheme: each elementary module is a very small but still physically significant grain of matter, and object shape and behavior emerge from built networks. GENESIS provides all the functionality necessary to specify these grains of matter and construct the networks in terms of both structure and parameters (figure 2).

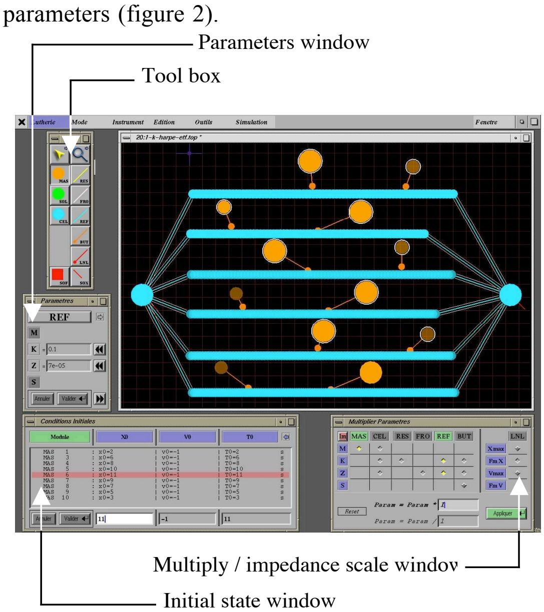


Figure 2: *"Lutherie" workbench with direct manipulation and basic editing windows.*

3.2.1. Toolbox and Structural Actions

The user can add or remove modules and connect or disconnect liaisons as if he was dealing with real masses and liaisons. Some organizational tools are also provided, which allow moving, rotating or dilating objects in order to change their symbolic organization on the workbench's 2D space. All the structural actions are handled through a toolbox.

3.2.2. Selection

Direct manipulation is deeply rooted on a selection paradigm. Each module can be easily added to or subtracted from the selection, with different mechanisms: module selection, area selection, module category selection, criteria-based selection or group selection (see below). Certainly, facilities to copy or move objects between workbenches are offered.

3.2.3. Parameter Editing.

Physical parameter edition is mainly based on the homogeneous properties of matter. By selecting modules and provided they are homogeneous, the user is able to choose their parameters (inertia, damping stiffness…) among some 'preferred values' or to choose their precise numerical value. A multiply tool is also provided. It allows simultaneous scaled modifications to the whole selection. By applying the same factor to all the parameters of the selected modules, it is easily possible to change the selection's impedance: its intrinsic behavior will not be modified but the way it interacts with other parts of the object will be affected. Alternatively, by multiplying only the stiffness parameters, the user can affect the frequency properties of the selection.

The non-linear LNL module required quite a special treatment: a two-level editing tool is provided (figure 3 on right side).

The first level displays the two shapes of the LNL but only allows modifying their amplitudes.

The shapes of non-linearities themselves, which are less frequently modified, are edited in a second window. In this advanced editing window, shapes may be forced to be symmetrical, smoothing can be specified and absolute positions of the control-points along deltaX (resp. deltaV) and force axis can be modified graphically or numerically. LNL modules allow a large diversity of non-linear interaction that can be physically consistent or not. The advanced editing window was thus designed in order to allow as much freedom as possible in the data specification. Note, however, that common LNL modules are provided pre-built.

3.2.4. Initial State Editing.

Each MAT module needs an initial state (position and velocity along the movement axis) to be specified. These initial conditions differ from physical parameters: they are not a property of matter, but a very simple way to specify a non-zero energy and a basic time input. They can be considered as elementary "gestures" that would be applied on objects. As a consequence they should not be edited by homogeneous selections, but module per module. The initial condition window displays a browser list with the initial conditions of the MAT modules the user has selected. GENESIS offers a third redundant initial state parameter which shows, when possible, the time when the concerned module, given its initial conditions, may have an effect on sound objects. For example, a MAT launched toward a sound object and connected with a BUT will strike the object after a time that GENESIS can compute. Such a time parameter is a very basic feature to deal with sound events, and thus to manage some kind of scheduling or control of musical evolution.

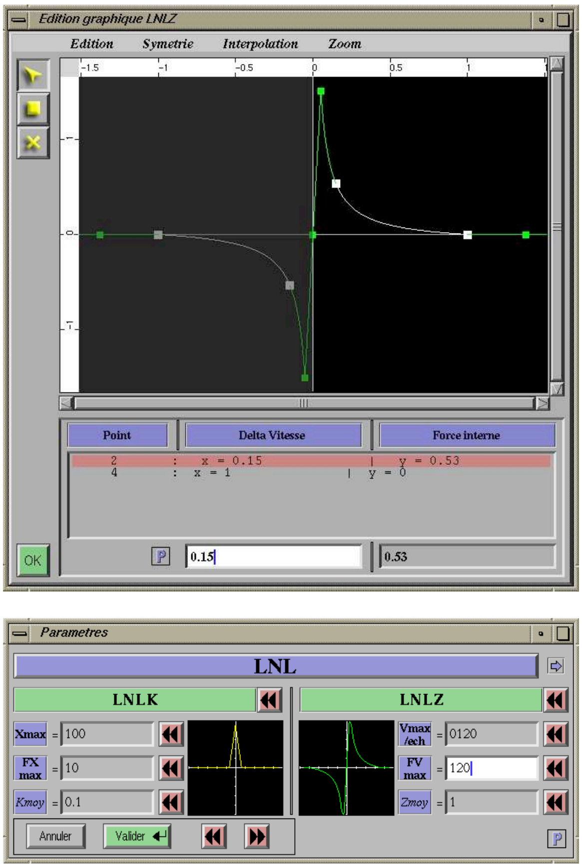


Figure 3: *LNL Non-linearity edition tools*
Top : advanced editing. Bottom: Simple editing

3.3. Macro-modularity features

Modeling with the mass-interaction paradigm implies the use of a large number of elementary modules. Users exhibit a highly modular way of thinking, establishing dependencies and hierarchy between modules. These groups, actually, can be either functional (let us say: a cord, a membrane, a low frequency "player-like" oscillator, etc) or morphologic (groups of modules of the same category or with homogeneous parameters for example). GENESIS provides three functionalities to support this macro-modular working process.

3.3.1. Selection sets

First, the user can whenever he needs nominate the current selection as a 'selection set' and assign a name and comments to it (see figure 4). Such a set can be easily re-selected by choosing it from a list or by double-clicking on one of its modules. Sets are non-exclusive: a module can belong to more than one set. Sets are thus a powerful tool for specifying structural relationships between modules, whatever the reason for this relationship may be.

Figure 4: *The set editing window*

3.3.2. *High Level Parameter Editing: meta-parameters*

Basic physical parameters are not sufficient to summarize structure properties. To control certain behaviors, users often have to think in terms of dependencies between parameters of different modules, or even to define a new parameter space set of axes.

For example, we know that for a given sound structure the quality of the transients in case of a plucking excitation is connected with the inertia M of the excitator and the quotient Q between stiffness and inertia [11]. M determines the brightness and Q determines the attack duration (or excitator/sound structure interaction duration). It would be of interest to let the user define a desired attack quality parameters instead of handling basic physical parameters, and to compute automatically the inertia and stiffness of the excitator. This example can however be generalized, which is taken into account with GENESIS' relation and meta-parameter system.

3.3.3. *Capsules*

Selection groups and relations are not sufficient to take into account the user's whole macro-modular way of thinking. GENESIS proposes in addition the capsule metaphor, which allows hierarchical editing. A capsule is precisely a macro-module.

Four kind of data are involved in its definition:

A content: a capsule is composed of an unspecified number of modules. It is, actually, a whole object in itself.

A structural 'surface', that is a list of the modules that are left accessible outside of the capsule and can receive physical connections.

A parametrical surface, that is the parameters that can be used to control the physical parameters of the inner modules. The surface parameters can be either basic physical parameters or meta-parameters that were defined by a relation between basic parameters. When defined, capsules' parameters behave like basic physical parameters in the object in which the capsule is inserted.

Finally, a name, some comments and display options. Display of a capsule can be full or compact: it can show off all the inner modules or only an icon with the structural surface (figure 5).

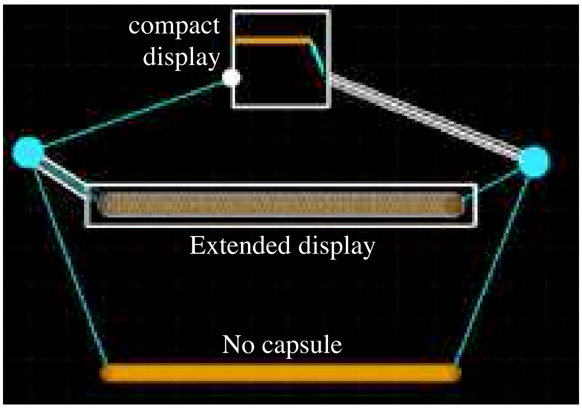


Figure 5: *Two capsules illustrating compact and extended display options*

On the workbench, a capsule is manipulated as a basic module. It may be, for instance, itself encapsulated in a higher-level capsule. A capsule's modules are no longer accessible to user. However, every capsule can be 'opened' when necessary on a new "lutherie" workbench.

3.4. Tools dealing with phenomena

Although the GENESIS user manipulates physical objets and is encouraged to think physical, the phenomena generated by these objects, such as sounds are, after all, important to the user. Thus we also designed tools that allow dealing with the phenomena to be generated. The aim is then to offer bridges between CORDIS-ANIMA models and the properties of the phenomena. This is achieved by *analyzing* a GENESIS object in order to give information on the phenomena it may generate, or on the contrary by *generating* a model according to a given set of desired behavior and/or phenomena (figure 6).

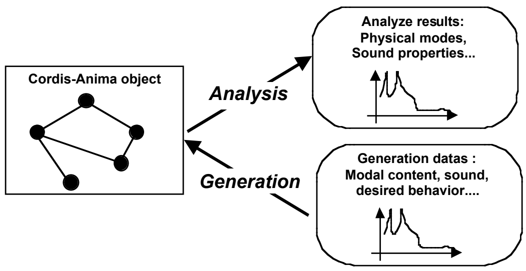


Figure 6: *Analyze and generation principles*

3.4.1. *Modal Analysis and Tuning*

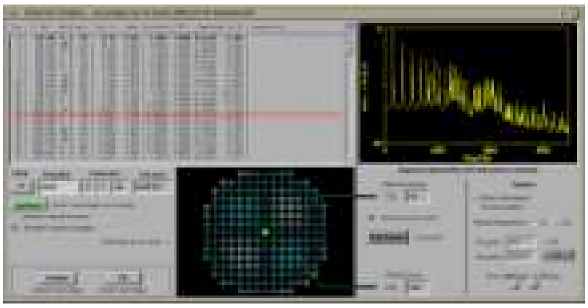
The first tool is the modal analysis system. A 1D mass-interaction model with masses and spring-frictions is a linear model. It is possible to compute the modes of the structures [12] and for each mode to determine its frequency, damping time and shape. GENESIS provides a analysis engine and a two-level ergonomy for modal analysis (Figure 7).

The first window displays the lowest-frequency mode properties. The user can then tune the object: he inputs the frequency and damping time he would like, and GENESIS multiplies damping and stiffness throughout the structure by some factor so that desired values and real values match.

Figure 7:
Modal analysis windows.

Left: *small display with fundamental mode characteristics.*

Below: *full display with mode list, frequency response and shape of a mode.*



The second window displays all the modes of the structure, its frequency-response for given excitation and observation points, and the modal shape of a chosen mode. Tuning is then possible on every mode – so that, for example, the second mode of the structure matches specific values. Note however that tuning will multiply the damping and stiffness throughout the analyzed structure, changing all the modes in the corresponding fashion. It may alternately be of interest to handle each mode separately, which is achieved by the reciprocal problem of structure generation.

3.4.2. Structure Generation

The aim here is to generate a CORDIS-ANIMA object whose behavior matches a given set of data. This reciprocal problem is mathematically difficult to solve – it may have no solution, or an infinite number of solutions. We have obtained however some preliminary results. The generation tool GENESIS currently proposes is thus able to generate an inhomogeneous cord-topology model that matches any desired mode list.

3.4.3. The modal chamber

The modal chamber is an alternate facility for matching modal data in a CORDIS-ANIMA model, but is oriented toward modal synthesis.

Consider a set of elementary physical oscillators. The resonating properties (frequency, damping) of each oscillator can be set independently. Provided we have a transform matrix that fixes each mode's importance, the set of oscillators becomes a modal model. It can be added to a more general mass-interaction object. A specific capsule is designed within GENESIS that implements such a modal chamber as an optional feature. At this point, the modal chamber is parameterized with explicit mode frequency and damping time and explicit mode amplitude at the access point. Other controls may be added soon to provide, when necessary, a more traditional approach to modal synthesis [13].

4. GENESIS' SIMULATION FEATURES

The standard GENESIS version is non real-time. The CORDIS-OFF engine is implemented in optimized independent background programs that can run in parallel. The data generated by the workbench's simulator are displayed in GENESIS in the simulation window.

Simulation is the main way to validate models and/or understand their behavior. It is used frequently within GENESIS. Considerable effort was devoted to the design of the simulation window (figure 8). Different appearances are possible for this window, according to the category of phenomenon the user want to look at: sound, sound signal, visualization or measures. The smaller aspect allows listening to the generated sound. By increasing the window's size, the user can:

Display the sound signal, and if needed perform measurements on it.

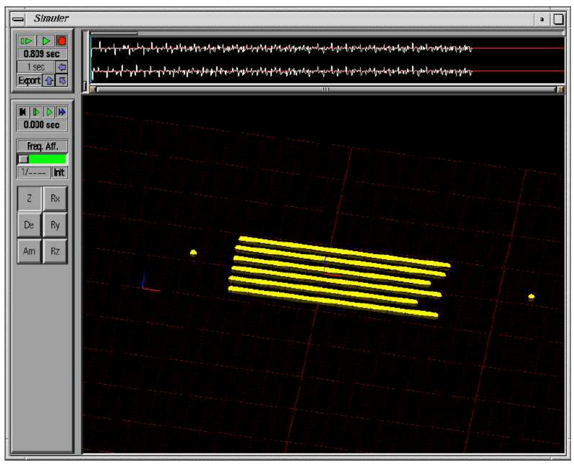
Display the object's movements currently calculated – and access facilities such as zooming and rotating the display, or modifying the simulation speed to slow down or accelerate observed movements. This visualization is of a great help when the model's behavior needs to be understood.

Display elementary measurements made on the object.

Figure 8:
The non real-time simulation window.

Left: *smaller aspect.*

Below: *Large aspect with sound signal view and simulated structure view.*



As a first step, it appeared to be more interesting to let users deal with large objects computed off-time than to perform real-time simulation on smaller ones. However, an experimental version of GENESIS supports the real time engine designed in the laboratory for multiprocessor computers with gesture interaction through force-feedback device [14]. This version is to be released soon.

5. 7 APPLICATIONS AND RESULTS

The design of Genesis has been made over many years in close collaboration with composers: Ludger Brummer, Hans-Peter Stubbe, Giuseppe Gavazza and Claude Cadoz, for example. The version 1.5 of GENESIS is now used in musical creation centers for both creative and pedagogical purposes by an increasing number of people. Many musical pieces have been created using the software, and some extracts and underlying physical structures will be commented briefly during presentation.

As an interesting result, they demonstrate that the mass-interaction paradigm is not only a sound synthesis technique but may have other musical interests: used through GENESIS, PM allows a whole creative process, including the design of musical macro-structure through large multi-scale objects (figure 9; see for explanations [15]).

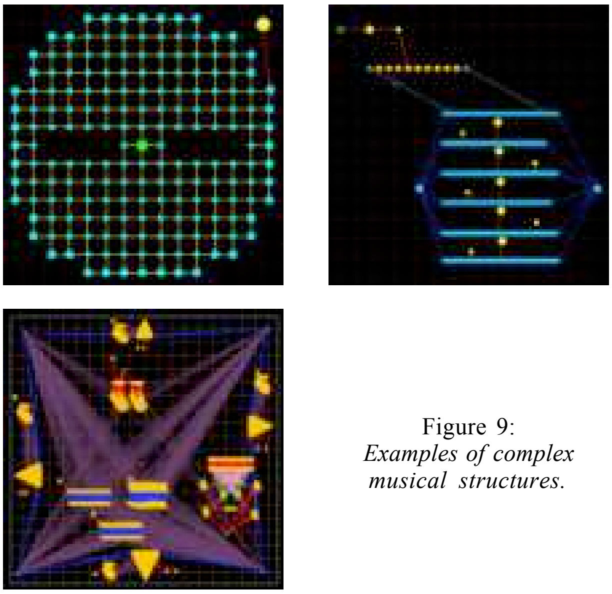


Figure 9: *Examples of complex musical structures.*

Other interesting but more anecdotal examples will be discussed. They show how some well-known synthesis or sound processing schemes, such as frequency modulation, additive synthesis or filtering, could be re-thought within GENESIS.

6. CONCLUSION AND FUTURE WORKS

Future work relative to Genesis will investigate some new features, especially those of a performance mode with time-explicit inputs. The version 1.5 of the GENESIS environment is already available on the SGI Unix platforms with the features described above. Users have expressed their satisfaction with using the software and investigating new creative processes based on the mass-interaction representation of matter.

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